NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE GENERAL SPECIFICATIONS

IRRIGATION WATER MANAGEMENT
SOIL MOISTURE MONITORING EQUIPMENT

(No.)

CODE 449

SCOPE

The work shall consist of furnishing and installing soil moisture monitoring equipment as part of irrigation water management plan. This equipment will provide data needed to perform effective irrigation water management that includes but not limited to:

1) soil water budget analysis for irrigation scheduling to avoid over- and under-watering, waste of water resources, and crop underperformance, and
2) Implementing demand management strategies such as deficit or limited irrigation to optimize water use in water scarce environments.

PUBLIC AND PRIVATE UTILITIES

Utilities are defined to be public or private, overhead and underground power or communication lines, and any pipelines. The landowner\operator\contractor shall conduct their own search and discovery for utilities in order to lessen or avoid potential damages, injuries or loss of life. Prior to installation, the landowner\operator should complete an OK-ENG-45 UTILITIES INVENTORY FORM to document known utilities in order to comply with State law prior to any ground disturbance and return it to a USDA-NRCS representative.

QUALITY CONTROL

Quality Control of all materials and construction procedures is the responsibility of the landowner\operator and contractor. NRCS will make periodic review(s) of the work for the benefit of the agency which will include the final construction check.

SENSOR SELECTION

Not all sensors are suitable for use in all soils, crops, and field conditions. Seek expert advice from NRCS and Cooperative Extension as well as manufacturer recommendations to select the appropriate type of sensing device that provides the desired accuracy, affordability, and ease of use while being suitable for the intended use in the prevailing soil, crop, and climate environment.

The choice of sensor needs to match the form of information and the manner of data accessibility required by the irrigator. Select the soil moisture device to perform satisfactorily at the expected soil salinity and temperature ranges encountered during the season or during the intended period of use that do not harm the sensor or negatively impact sensor longevity and performance.

Effective use of soil moisture measurements requires experience and judgment. Some soil moisture measurements are qualitative in nature like using the ‘Feel and Appearance Method’, while others provide quantitative reading of soil moisture status. The quantitative methods can be roughly categorized into two classes: those that provide the soil moisture content (on either gravimetric or volumetric basis) and those that provide the soil moisture matric potential (commonly referred to as tension or suction), which indicates the effort required by root systems to extract water from the soil. The most useful measurement unit in irrigation water management is volumetric soil moisture content (i.e., the volume of soil moisture divide by the volume of bulk soil, which is equivalent to depth of water per unit thickness of soil). Changes in soil moisture in sandy soils are generally small due to its narrow range of plant available moisture and the measurement of soil moisture tension is preferred.

The technology used in sensors to determine soil moisture content or tension comes in a variety of ways. Common methods include but are not limited to measuring: electrical resistance through porous blocks like gypsum or other granular matrix, moisture potential by tensiometers with porous ceramic cups, neutron scattering via neutron probes, and soil dielectric behavior methods using: time domain reflectometry (TDR), time domain transmission (TDT), frequency-domain reflectometry (FDR), capacitance, and amplitude-domain reflectometry (ADR or Impedance).

Major types of sensors are listed in the table below with their advantages and disadvantages. For detail discussions, refer to NEH, Part 652, Irrigation Guide, Chapter 9, Irrigation Water Management and the referenced publications.

Method	Advantages	Disadvantages
Electrical resistance (tension)	inexpensive, low maintenance, easy to install/read, wireless and remote data retrieval capable, no calibration	output variability, slower response, sensitive to temperature & salinity (gypsum)
Tensiometers (tension)	less expensive, easy to install/read, no calibration, no salinity sensitivity, portable or stationary	higher maintenance, freezing, narrow range to 100 kPa
Frequency Domain: Capacitance and FDR (moisture content)	higher accuracy, easy to log and transmit data, wireless and remote retrieval capable, portable or stationary, full range, profiling via access tube	highly sensitive to gaps and stones next to sensor, more expensive, small sampling area, temperature sensitivity, soil-specific calibration recommended
Time Domain: TDR and TDT (moisture content)	high accuracy, easy to log and transmit data, wireless and remote retrieval capable, improved calibration, portable or stationary, full range	highly sensitive to gaps and stones next to sensor, more expensive, small sampling area, temperature sensitivity
ADR or Impedance (moisture content)	high accuracy, easy to log and transmit data, not affected by temperature, tolerant of high saline conditions, portable or stationary, full range	highly sensitive to gaps and stones next to sensor, expensive, small sampling area, soil-specific calibration recommended
Neutron probe (moisture content)	highest accuracy, largest sampling area, full range, no temperature or salinity sensitivity, profiling via access tube	high cost, high regulatory requirement, operator certification, no remote data retrieval, heavy

DATA RECORDING

Significant improvements in soil moisture sensors have occurred in recent years, making them more accurate, user-friendly, reliable, and economical. Soil moisture sensors are available in a wide variety with features ranging from manual readout to automated recording and storing capabilities with optional remote retrieval and online deployment of data. Multi-horizon profile measurements are usually accomplished by installing individual sensors at each soil horizon depth. Some newer sensors, including FDR and capacitance probes, provide simplified profiling via access tubes.

The need for sensor calibration against local soil is also a determining factor when selecting a sensor type. Depending on the sensor type, calibration can be demanding, especially when there is a need to calibrate against on-site volumetric soil moisture content at various horizon depths and under full plant available moisture content from wilting point to field capacity. Most sensors that measure soil moisture tension, like resistance blocks and tensiometers, do not need calibration. Nearly all other sensors must be either fully calibrated on-site or at a minimum evaluated to ensure that factory calibration is sufficiently appropriate for the local soil. Follow manufacturer or any scientifically-based recommended procedure for on-site calibration of the sensor.

Make and record soil moisture measurements on a systematic basis and in regular intervals to allow effective scheduling of irrigation and management of soil profile moisture. However, irrigators shall manually evaluate soil moisture data and not fully rely upon soil moisture monitoring equipment for critical management decisions. At a minimum, the soil moisture shall be manually checked at least once using the ‘Feel and Appearance Method’ (Program Aid 1619) during all the critical growth stages of the crop life throughout the growing season and the results recorded on the appropriate data sheet. The critical growth stages typically include the following: Establishment, Vegetative, Flowering (Silking, Bud Formation), Yield Formation, and Ripening. During the reproductive stages (Flowering, Yield Formation, and Ripening) it is critical that the ‘Feel and Appearance Method’ check be performed at the beginning of these stages. Manually evaluating the soil moisture is required to be done, as stated above, to ensure that sensors are not in need of recalibration, repair, or replacement. Even though it is not required, manually checking the soil moisture is encouraged on a weekly basis to confirm the soil moisture monitoring equipment data, especially during the reproductive growth stages.

All irrigation systems serving the irrigated field where soil moisture monitoring equipment is planned to be installed shall have an installed flow meter. This device shall be capable of providing data needed to manage efficient use of water to promote desired crop response and optimize use of available water supplies. For additional information and/or criteria pertaining to flow meters, refer to the Structure for Water Control (587) Standard and Specification.

SITE SELECTION

Regardless of the method used to measure soil moisture status, one measurement is hardly ever representative of the field. Follow manufacturer recommendations supported by established scientific protocols to select application location in the field. To measure soil moisture change for the purpose of scheduling irrigation, install stationary or sample portably several site locations in each field and each horizon (or if homogeneous at about 6 inch depth increments) at the site. Multiple sites in a field are used to improve confidence in determining when and how much water to apply.

For representative readings, install the sensor in the dominating or principle soil type, within the active root zone of the crop. Ensure proper sensor orientation in the soil profile. Ensure access tubes, if any, extend to the bottom of the active root zone to allow sufficient depth for profile measurements. Avoid installation at high or low spots and near or at rapid slope changes. Avoid areas prone to collect runoff or get flooded. Ensure the sensor is reasonably accessible, especially during high crop canopy conditions, if frequent visits for maintenance or data retrieval are needed.

INSTALLATION

Poor installation techniques are the number one reason for bad soil moisture data. Sensors come in all shapes and must be installed properly following manufacturer recommendation. Generally, the deeper the installation of the sensor or the access tube, the greater the difficulty for proper installation. Also, very dry sandy as well as clayey soils with shrinking and swelling characteristics and stony soils provide substantial challenge during access tube and sensor installation.

Avoid simply making a hole, placing or dropping the sensor at the bottom, and backfilling. Use recommended insertion, boring, and installation tools that is specific to the sensor and the access tube to be installed. Avoid using different material access tubes in a given field. Minimize roots and soil structure destruction during installation. Ensure soil moisture sensors as well as access tubes are in full and tight contact with the surrounding soil for accurate readings. Avoid placing sensors and access tubes at or near air voids, rocks, and large roots and residue. Strive for a direct, clean insertion of sensors into naturally consolidated soil to secure rapid and representative moisture readings.

Sandy soils need to be damp for installation since they tend to collapse when dry. It may be nearly impossible to keep dry sand from collapsing when boring a hole for access tube installation. If the soil is too hard or gravelly to safely allow installation by insertion or via a pilot hole, consider slurry bedding of sensors. Slurry bedding involves screening the soil collected from the sensor depth, mixing into thick slurry to obtain full soil contact. Even in clean installation of deep sensors, pouring of slurry around the sensor helps with soil contact. Prepare slurry using the same soil from the depth where the sensor is to be installed. Use of slurry made of a texturally-different soil introduces error and non-representative reading. Allow time for the slurry to come to moisture equilibrium with surrounding soil before taking moisture readings. Slurry mixes take time, some up to several weeks, to come to moisture equilibrium, especially at deeper depths and in clayey soils.

Avoid creating conditions during installation that increases preferential flow of surface water to the sensor. Avoid installing sensors where tillage operations increase soil susceptibility to collapse or shifting. Tillage practices, such as deep ripping, can create surface cracks and subsurface tunnels (especially if tilled wet) that collapse upon wetting. Create a small surface mound of soil around the sensor to avoid surface puddling and improve compaction and sealing around wires to help prevent preferential water from reaching the sensor and induce erroneous, elevated readings.

PHYSICAL PROTECTION

Carefully map and flag the sensor locations for ease of find and end-season retrieval. Before installation, place a rubber stop or other seal on the bottom of all access tubes to prevent entry of moisture. After installation, place a rubber stopper or a cap on top of the access tubes to prevent moisture entry. Tensiometers are liquid filled and will freeze and break if installed too early in the spring or left in the field too late in the fall.

Protect all sensors, recorders and appurtenances from hazards presented by traffic, farm operations, freezing temperatures, precipitation, fire, lightning, thermal expansion and contraction. Take reasonable measures to protect the sensor, recorder and appurtenances from potential vandalism. Protect all exposed wiring against animals, UV light, and field traffic by placing them inside PVC conduit or braided stainless steel sheathing.

Provide physical support for recorders, communication devices, and solar panels placed at or above the soil surface to provide stability against external and internal forces.

LAWS AND REGULATIONS

Ensure installation, operation, and transport of all soil moisture sensors and communication devices comply with all federal, state, Tribal and local laws, rules, and regulations. Use of neutron probe or other radioactive soil moisture probes demand strict regulatory requirements as well as documented radiation safety training certifications and assigned radiation badges for the owner and operator before handling the probe.

CERTIFICATION AND GUARANTEE

The installing contractor/vendor shall certify to the landowner/operator that the materials and installation comply with the requirements of these specifications. The contractor/vendor shall furnish the landowner/irrigator a written guarantee against defective workmanship and materials to cover a period of not less than one (1) year.

The landowner/irrigator shall furnish the NRCS a copy of the contractor’s/vendor’s certification and guarantee, which will be made a part of the supporting records of the irrigation water management.

ADDITIONAL CONSTRUCTION DETAILS

Refer to the appropriate approved design plans for site specific additional items of work and construction details.

NRCS, OK
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